

RESEARCH BRIEF

MICROSCALE PUMPS, MOTORS AND TURBINES

The problem

Today’s soldiers typically carry some 100 pounds of weapons, body armor, simple medical supplies, food and water, and an array of digital communications and computing devices. They also work in extreme environments, where every one of these pounds matters, including the 20 pounds of lithium ion and other batteries needed to power the electronic devices.

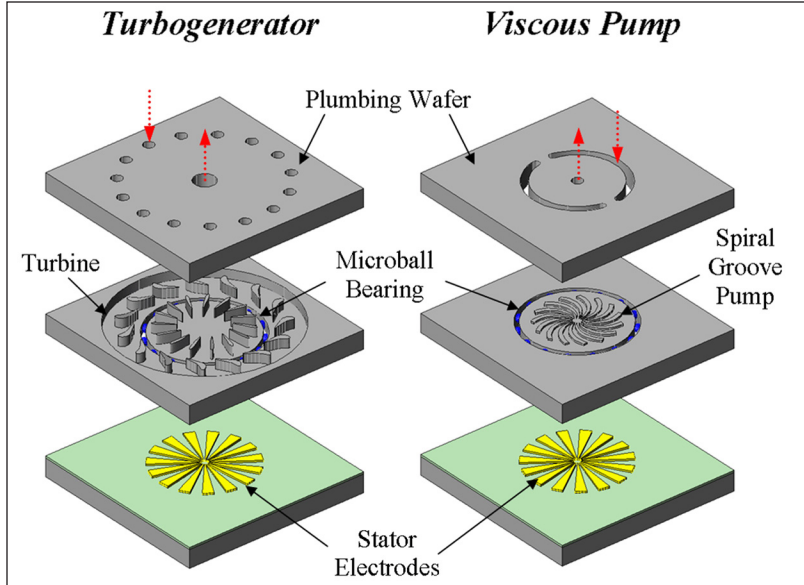
The challenge

If batteries, power generators, pumps, motors and other devices could be made smaller while still delivering the needed functionality, soldiers would not have to carry as much weight in the field.

The research

For the first time, a level of miniaturization for machines like that achieved over the last decades in electronics has been achieved. A team of researchers led by Professor Reza Ghodssi (ECE/ISR) has succeeded in manufacturing and integrating reliable, robust micromachines—tiny pumps, motors, and turbines that, integrated in a microscale liquid-fuel power generation system, will significantly reduce a soldier’s battery load. The advances also hold promise for health care (micropumps for implantable medical devices) and first responders (bio-chemical sensors).

The central component of their research is the microball bearing. Ball bearings are spheres made of metal, silicon, or other substances that when placed between two surfaces, such as the components of a motor or generator, allow those components to move with less friction and heat than if they were in direct contact with each other. The less friction and heat, the faster the components can spin and the more power they can produce. Conventional ball bearings are used in everything from jet engines to dentists’ drills—devices in which parts move at high speeds in close proximity to each other.



Schematics of a turbogenerator and a viscous pump, two of the micromachines made possible by microball bearing technology.

Using well-known manufacturing techniques similar to those used in the semiconductor industry to make computer chips, the researchers have successfully miniaturized ball bearing support mechanisms with microballs as wide as a few human hairs and nearly invisible to the naked eye. Using these components, they have built tiny silicon pumps, motors, and turbines demonstrating rotational speeds of up to 87,000 rpm, comparable to the speed of large-scale machinery.

To create their machines, the Ghodssi team first had to conquer microscale “tribology”—the friction, wear, and lubrication of tiny rolling components. They then applied this knowledge in building different types of micromachines using conventional manufacturing processes, and finally in integrating these devices into tiny systems that can reliably accomplish a task such as power generation without burning up.

Rather than focus on an arbitrary performance specification for micromachines, Ghodssi focused on feasibility—building pumps and motors that are fast enough to do the jobs required, reliable enough to last, and easy enough to manufacture in the real world. As in the miniaturization of electronics, the team expects to achieve successive generations of higher and higher

efficiency and refinement in micromachine systems, and to see the creation not only of new defense and medical products, but of entirely new technologies no one has yet imagined.

The potential

For troops on the battlefield, small-scale combustion generators using micromachines, combined with batteries in hybrid technologies, will significantly reduce the soldier's load. Bruce Geil, acting branch chief for the Power Components Branch of the U.S. Army Research Laboratory, says, "The Army needs small-scale, liquid-fueled power generators that can provide higher energy, at lighter weight and lower cost, than current fielded power sources. Dr. Ghodssi's team is developing key fuel delivery and electrical generator components to meet our requirements."

Micromachine systems also will help power land or air-based micro vehicles that will venture into risk-filled environments ahead of soldiers or first responders and send back information. Microgenerators fabricated completely in silicon and supported on microball bearings could power the vehicles' electrical systems without weighing them down.

Funding

Army Research Office, Army Research Laboratory, and National Science Foundation.

Related publications

M. McCarthy, C.M. Waits, and R. Ghodssi, "Dynamic Friction and Microturbine Performance Using a Planar-Contact Encapsulated Microball Bearing," Proceedings of the 2008 Solid-State Sensor, Actuator, and Microsystems Workshop, pp. 170-173, Hilton Head Island, SC, June 1-5, 2008.

N. Ghalichechian, A. Modafe, M. Beyaz, and R. Ghodssi, "Design, Fabrication, and Characterization of a Rotary Micromotor Supported on Microball Bearings," Journal of Microelectromechanical Systems (JMEMS), vol. 17, No. 3, pp. 632-642, 2008.

M. I. Beyaz, N. Ghalichechian, and R. Ghodssi, "Toward an Autonomous Electrostatic Micromotor: Integrated Feedback Control," Proceedings of the 21st IEEE International Conference on Micro Electro Mechanical Systems (MEMS 2008), pp. 483-486, Tucson, AZ, USA, January 13-17, 2008.

C. M. Waits, B. Geil, and R. Ghodssi, "Encapsulated Ball Bearings for Rotary Micro Machines," Journal of Micromechanics and Microengineering (JMM), Vol. 17, pp. S224-S229, 2007.

Links

MEMS Sensors and Actuators Lab: www.ece.umd.edu/MEMS/index.html

Videos, photos and more: www.eng.umd.edu/media/pressreleases/pr092208_bearings.html

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